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Milk recording data highlight improvements in fertility and somatic cell counts but worsening longevity for the UK national dairy herd

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HIGHLIGHTS

- Herd size has increased but the proportion of cows in lactation 1 remained stable.
- Exit rates have increased in line with cows exiting the herd at a younger age.
- All fertility parameters have significantly improved, including conception rates.
- Milk yield per cow per year peaked at 8797 kg in 2021 but decreased in 2021/2022.
- The percent of cows dried-off with no SCC recordings ≥ 200,000 cells/ml increased.

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ABSTRACT

Benchmarking of key performance indicators (KPIs) can be used by farmers and technical advisors to indicate areas for improvement and enable them to make more informed management decisions. Data for selected KPIs are readily available from a variety of sources. However, longitudinal data covering a mixture of KPIs in the same dataset are limited. Herein, milk recording data are used from a cross-section of 195 UK Friesian/Holstein herds which have milk recorded for a minimum of 10 years to examine trends in the median herds' KPIs from 2014 to 2023. Herd size has increased by 15.8 % but cows are being culled at a younger age. Fertility parameters have improved, most notably conception rates increased from 32.9 % to 40.0 % and the percent of cows conceived 100 days post-partum (DPP) increased from 30.4 % to 39.0 %. From 2014 to 2021, milk yield per cow per year increased from 8394 kg to 8797 kg and lifetime milk yield per cow per day increased from 11.7 kg to 12.8 kg, but both decreased slightly in 2022 and 2023. Many somatic cell count (SCC) related parameters improved between 2014 and 2023. Notably, the percent of cows dried-off with no SCC recordings ≥ 200,000 cells/ml during a completed lactation increased from 39.7 % in 2014 to 51.0 % in 2023. Therefore, fertility and SCC related KPIs have demonstrated improvements but milk production appears to have peaked and recently plateaued, and the longevity of cows appears to have shortened. Decreased longevity appears at odds with pressure on farmers to attain environmental targets which would favour cows with longer, more productive lives.

1. Introduction

In 2023, the UK milking herd totalled 1.84 million cows (AHDB, 2023a) across 7500 farms (AHDB, 2023b). Since 2014, the number of UK dairy producers has reduced by almost one-fifth (19.5 %) (AHDB, 2023b) but the size of the UK milking herd has remained stable (AHDB, 2023a) with the average UK dairy herd size increasing from 132 cows to 160 cows (AHDB, 2023a). UK dairy farmers have faced unprecedented challenges over the past decade. On-farm production costs, such as feed, fuel and energy, have soared (Kite Consulting, 2021), farmgate milk prices have varied widely from 19.95 pence per litre to 51.60 pence per litre (AHDB, 2023c) and pressure for dairy farms to become more environmentally sustainable has increased (Dairy UK, 2021). In the future, farmers will be further challenged by the basic payment scheme

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being phased out by 2027 (House of Commons, 2021).

Data for selected key performance indicators (KPIs), particularly milk production, are readily available (AHDB, 2023d) and a wide variety of KPIs have become available for use by farmers and technical advisors, such as; concentrates usage and costs, milk production versus milk price per litre, and margins over purchased feed (Kingshay, 2024). Milk recording data are an invaluable source of data for KPIs relating to herd demographics (including longevity), fertility, milk production and health. Based on information from the Agriculture and Horticulture Development Board (AHDB) (2023b) on the number of dairy producers in Great Britain and results from a milk recording systems survey (ICAR, 2015), approximately 50 - 55 % of dairy herds in England and Wales collect milk recording data.

Benchmarking KPIs enables individual herds to assess their own performance against relevant reference values. The annual 500 herds study published for the University of Reading by PAN Livestock Services provides quartile values indicating the performance of the top and bottom 25 % of herds, along with the median herd value, for a wide range of KPIs (PAN Livestock Services, 2024). Farmers with access to KPI calculations for their own individual herds, for example by using the dairy recording software InterHerd+ (PAN Livestock Services Ltd, Reading), can readily assess whether their herd performance is exceeding the standard set by the top 25 % of herds or below the threshold set by the bottom 25 % of herds. These comparisons with benchmarks can be used by farmers and technical advisors to indicate areas for improvement and enable them to make more informed management decisions.

Despite historical gains in the efficiency of dairy production, a variety of challenges remain. For example, dairy cattle breeding has previously focused on milk output (Lucy, 2001), inadvertently prompting infertility and udder problems to become the most common causes of involuntary culling (Chiumia et al., 2012). Involuntary culling reduces the longevity of cows, negatively affecting both economic and environmental outcomes. Improving the productive lifespan of dairy cows from 3.6 lactations (PAN Livestock Services, 2024) closer to the economic optimal productive lifespan of 5.0 lactations (De Vries, 2020) would improve economic efficiency and reduce the climate impact of milk production (Grandl et al., 2019). Access to KPI data covering varying aspects of dairy production supports more effective on-farm management decisions provided attention is paid to the full breadth of KPIs to ensure that improvements in one KPI are not unduly detrimental to another.

Although KPIs, particularly milk production, are readily available from a variety of sources, a dataset containing data for a mixture of KPIs from the same herds over a long period of time is a rare resource and there is an absence of peer-reviewed literature detailing temporal trends in KPIs. Considering the new and continued challenges facing the UK dairy industry, the documentation of KPI trends is crucial to enable the industry to make more informed policy decisions. Benchmarking of herd demographic, fertility, milk production and health-related KPIs for 500 UK Holstein-Friesian dairy herds has been conducted annually since 2010 (PAN Livestock Services, 2024).

This study examined the temporal trends in demographics (including longevity), fertility, milk production and health. Data were used from 195 herds that had milk recorded continuously for a minimum of 10 years. We show that fertility and SCC related KPIs have demonstrated improvements but milk production appears to have peaked and recently plateaued, and the longevity of cows appears to have shortened.

2. Materials and methods

This study made use of a dataset stored within the dairy data management software InterHerd+ (PAN Livestock Services Ltd) which is used for the annual 500-herd KPI reports produced for the University of Reading by PAN Livestock Services (2024). The 500 herds in this dataset were originally selected in 2010 from herds in UK that routinely milk record with the milk recording organisation National Milk Records (NMR). The starting criteria for selection were that the herds were comprised predominantly of black and white breeds (Holstein, Friesian, Holstein-Friesian) with a herd size ≥40 cows. To ensure data quality, herds were excluded if there were data missing for any KPI presented in the study, or their data file contained obviously inadequate data. For example, herds which recorded one or fewer services per conception (resulting in a conception rate exceeding 100 %) a culling rate over 100 %, or a calving interval longer than 600 days were excluded from the study. The original sample of 500 herds was selected from all herds meeting these criteria using random numbers to ensure a representative cross-section of herds. Following the initial random selection carried out in 2010, the same herds have been retained within the sample for each subsequent annual report, as far as possible. However, each year around 10 % of the sample either cease recording or fail to meet data quality criteria. To maintain the sample size at 500 herds, these herds are replaced by randomly selecting new herds that meet the required criteria.

Sample size calculations were performed using G*Power Version 3.1.9.7 (Faul et al., 2007). A priori power analysis was conducted based on the following input parameters; medium effect size, $f = 0.25$ (Cohen, 1988), $\alpha = 0.05$, power ($1 - \beta = 0.95$), number of groups = 1, number of measurements = 10, correlation among repeated measures = 0.5 and nonsphericity correction = 1. This analysis indicated that for parametric analysis a sample size of 20 would be needed (Supplementary Figure 1). As advised by Lehmann (2006), for non-parametric analysis the sample size would need to be increased by 15 %, so a sample size of 23 would be needed. However, data from 195 herds which had been included in the annual KPI reports for every year from 2014 to 2023 (10 years) were available, and these herds were examined in this study (Supplementary Table S1). The KPI values were produced by a single continuous procedure coded in SQL, that remained unchanged for the entire period analysed here, and placed in an output grid. The query is set to output annualised parameters for each herd to minimize the impact of short term seasonal variations. Each annual period runs from 01 September to 31 August the next year, to approximately cover one calving cycle of the most common autumn calving herd type. Each row of the output grid included the calculated KPIs on herd demographics, fertility, milk production and somatic cell count (SCC, whereby cells counted comprise mainly leukocytes and epithelial cells) for each individual herd for each year. Definitions of each parameter are provided in Supplementary Table S2. To examine the trends in KPIs, the annual outputs from the years ending August 2014 to August 2023 were used. For brevity in the subsequent text we refer to results as being “in 20XX” where this implies “in the 12 months to 31 August 20XX". The output grids were exported to Statistix version 10 (Analytical Software, Tallahassee, USA) and an Excel workbook (Microsoft Corporation, 2016). Within Statistix version 10, annual summary statistics were generated and Friedman’s nonparametric one-way analysis of variance was used to determine if the observed changes in KPIs between 2014 and 2023 were significant ($p < 0.05$). Dunn’s all-pairwise comparisons test was used to identify the significant between-group differences with alpha (probability of a type I error) set at 0.05. Figures showing the percentage changes for each KPI over time were produced in an Excel workbook.

3. Results

The median values of KPI’s for the 195 herds across all years are shown in Table 1, along with the p values for Friedman’s nonparametric one-way analysis of variance. Figs. 1–7 summarise the changes in median KPI value relative to the values in 2014.

Across the 10 year period, the median herd size significantly ($p < 0.05$) increased by 15.8 % but the median herd’s proportion of cows in lactation 1 remained broadly stable ($p > 0.05$) (Fig. 1). The exit rate (%) for the median herd significantly increased from 22.7 % to 27.6 %, in line with cows exiting herds at a significantly younger age with

Table 1
Examination of median herd values for key performance indicators (KPIs) from 2014 to 2023 using Friedman's nonparametric one-way analysis of variance ($n = 195$ herds).

Key performance Indicators	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	*p-value*
Herd demographics/longevity											
Herd size (number of cows)	152^{D}	154^{C}	162^{BC}	164^{ABC}	163^{A}	161^{AB}	167^{A}	175^{AB}	168^{AB}	176^{A}	<0.01
Cows in lactation 1 (%)	27.8	29.2	28.0	28.7	28.7	28.5	27.9	28.5	28.6	28.5	0.95
Productive life (days)	1,483^{A}	1,473^{A}	1,397^{AB}	1,375^{BC}	1,356^{BC}	1,336^{BC}	1,344^{C}	1,309^{C}	1,386^{BC}	1,383^{BC}	<0.01
Age at exit (days)	2,355^{A}	2,324^{A}	2,252^{B}	2,240^{BC}	2,225^{BC}	2,189^{C}	2,203^{C}	2,166^{C}	2,180^{C}	2,198^{C}	<0.01
Exit rate (%)	22.7^{D}	23.6^{CD}	25.9^{ABC}	25.8^{BC}	26.5^{AB}	25.9^{AB}	27.8^{A}	27.1^{AB}	26.5^{AB}	27.6^{AB}	<0.01
Fertility											
Age at 1st calving (months)	878^{A}	859^{AB}	841^{BC}	832^{CD}	834^{CD}	827^{CD}	828^{D}	807^{E}	796^{E}	797^{E}	<0.01
Cows served 80 DPP (%)	55.6^{B}	58.5^{AB}	56.7^{B}	61.2^{A}	58.3^{B}	58.9^{AB}	60.2^{AB}	59.7^{AB}	57.7^{AB}	58.1^{AB}	0.01
Service intervals at 18–24 days (%)	33.8^{F}	34.0^{EF}	35.1^{DEF}	35.4^{DEF}	35.8^{CDEF}	37.0^{CDE}	38.1^{BCD}	37.7^{ABC}	40.8^{AB}	41.7^{A}	<0.01
Calving to 1st service interval (days)	86.1^{F}	80.2^{EF}	81.9^{DEF}	79.0^{DEF}	80.8^{CDEF}	80.3^{CDE}	79.8^{BCD}	80.0^{ABC}	82.4^{AB}	80.5^{A}	<0.01
Cows conceived 100 DPP (%)	30.4^{EF}	31.7^{F}	34.3^{DEF}	35.0^{CDE}	34.7^{CDEF}	35.8^{BCD}	36.6^{ABC}	36.5^{AB}	37.6^{A}	39.0^{A}	<0.01
Conception rate (%)	32.9^{C}	31.6^{C}	34.4^{B}	33.7^{B}	34.1^{B}	36.1^{B}	36.0^{B}	37.4^{B}	38.8^{A}	40.0^{A}	<0.01
Calving interval (days)	411^{A}	408^{AB}	407^{BC}	401^{CD}	401^{CD}	400DE	398^{DEF}	397DE	394^{EF}	394^{F}	<0.01
Production											
Milk / cow / year (kg)	8,394^{CDE}	8,221^{E}	8,188^{DE}	8,194^{E}	8,283^{DE}	8,608^{AB}	8,771^{AB}	8,797^{A}	8,386^{CD}	8,540^{BC}	<0.01
Lifetime milk / cow / day (kg)	11.7^{DE}	11.7^{E}	12.0^{DE}	11.8^{CDE}	12.2^{BCD}	12.7^{A}	12.5^{AB}	12.8^{A}	12.1^{BCDE}	12.5^{ABC}	<0.01
Milk protein (%)	3.27^{E}	3.29^{D}	3.26^{E}	3.26^{E}	3.27^{E}	3.33^{AB}	3.31^{BC}	3.30^{CD}	3.33^{BC}	3.36^{A}	<0.01
Milk protein yield per cow / year (kg)	267^{CDE}	261^{E}	260DE	261^{E}	263DE	274^{AB}	279^{AB}	280^{A}	267^{CD}	272^{BC}	<0.01
Milk fat (%)	4.00^{EF}	3.95^{F}	4.05^{D}	4.01^{DEF}	4.04^{DE}	4.02^{DEF}	4.13^{C}	4.20^{BC}	4.19^{B}	4.28^{A}	<0.01
Milk fat yield per cow / year (kg)	336^{C}	332^{D}	338^{C}	334^{CD}	336^{C}	350^{B}	358^{AB}	370^{A}	353^{B}	358^{A}	<0.01
Somatic cell count											
Average SCC ('000 cells/ml)	178	173	177	173	176	172	171	172	164	170	0.09
SCC ≥200,000 cells/ml (%)	19.1^{A}	19.1^{A}	18.3^{AB}	18.4^{ABC}	17.4^{BCD}	17.3^{CDEF}	17.2^{BCDE}	16.2^{DEF}	15.6^{EF}	15.7^{F}	<0.01
SCC ≥500,000 cells/ml (%)	7.22^{A}	6.88^{AB}	7.00^{A}	6.85^{AB}	6.83^{AB}	6.84^{AB}	7.03^{AB}	6.78^{AB}	6.44^{B}	6.57^{AB}	0.02
Cows dried-off with no SCC >200,000 cells/ml (%)	39.7^{G}	41.5^{G}	42.9^{EFG}	42.7^{FG}	43.9^{DEF}	44.9^{CDE}	48.2^{ABC}	47.6^{BCD}	49.4^{AB}	51.0^{A}	<0.01
Chronic SCC ≥200,000 cells/ml (%)	10.34^{A}	10.35^{A}	9.36^{AB}	9.48^{AB}	9.19^{BC}	8.91^{BCD}	8.56^{CD}	8.07^{CD}	7.86^{D}	8.10^{D}	<0.01

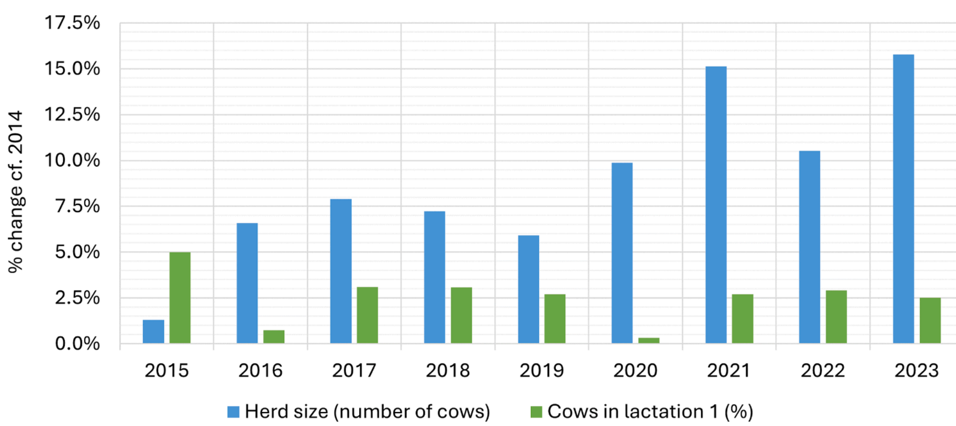

Fig. 1. Percentage change in median herd size (number of cows) and median % of cows in lactation 1 compared to herd values in 2014.

significantly shorter productive lifespans. The median herd's average age at exit decreased by 6.7 % and average cow productive life (age at exit minus age at first calving) decreased by 6.8 % (Fig. 2, Table 1).

All fertility parameters have significantly improved since 2014 (Table 1). The median herd's average age at first calving (AFC) decreased by 9.3 % over the timeframe of the study. The median herd's percent of cows served by 80 DPP and average calving to first service interval demonstrated no clear pattern. However, the median herd's percent of service intervals 18–24 days apart, a measure of accurate heat detection, gradually increased from 33.8 % to 41.7 % and percent of cows conceived by 100 DPP gradually increased from 30.4 % to 39.0 %. Likewise, the median herd's conception rate increased from 32.9 % to 40.0 % and calving interval gradually decreased by 4.1 % (Fig. 3).

Milk production, milk protein and milk fat significantly increased across the 10-year period (Table 1). Milk yield per cow per year (kg) initially decreased by 2.5 %, before gradually increasing to a peak in 2021, but reduced to 1.7 % above 2014 levels, in 2023. Likewise, the median herd's average milk yield per cow per day of life (kg) increased by 9.3 % to a peak in 2021, but reduced to 6.9 % above 2014 levels, in 2023 (Fig. 4). The median herd's average milk protein (%) was similar from 2014 to 2018 and from 2019 to 2022 but then increased to 3.36 % in 2023, compared to 3.27 % in 2014. Changes in average milk fat (%) were steadier, the median herd's average milk fat (%) increased from 4.00 % in 2014 to 4.28 % in 2023 (Fig. 5). The trends in milk fat and milk protein yields (kg per cow per year) naturally followed the trends in milk production and composition (Fig. 5).

Reductions of 4.5 % in the median herd's average SCC (000′ cells/ml) were insignificant ($p = 0.09$), but all other SCC-related KPIs significantly improved across the 10-year period (Table 1). For many SCC parameters, values improved until 2022 but slightly worsened in 2023. The median herd's percent of milk samples with SCC ≥ 200,000 decreased from 19.1 % in 2014 to 15.6 % in 2022 and 15.7 % in 2023 (Fig. 6). The median herd's percent of milk samples with a SCC ≥ 500,000 followed the same pattern. Likewise, the median herd's percent of milk samples

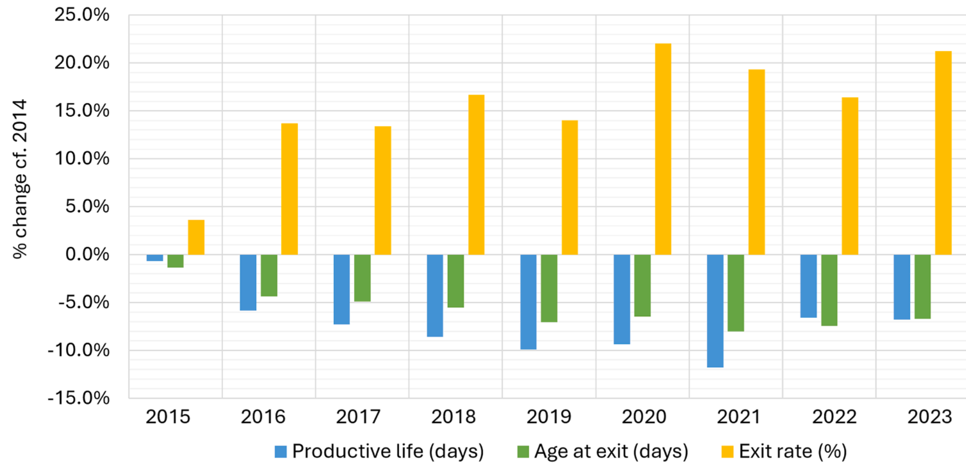

Fig. 2. Percentage change in median exit rate (%), median productive life (days) and median age at exit (years) compared to herd values in 2014.

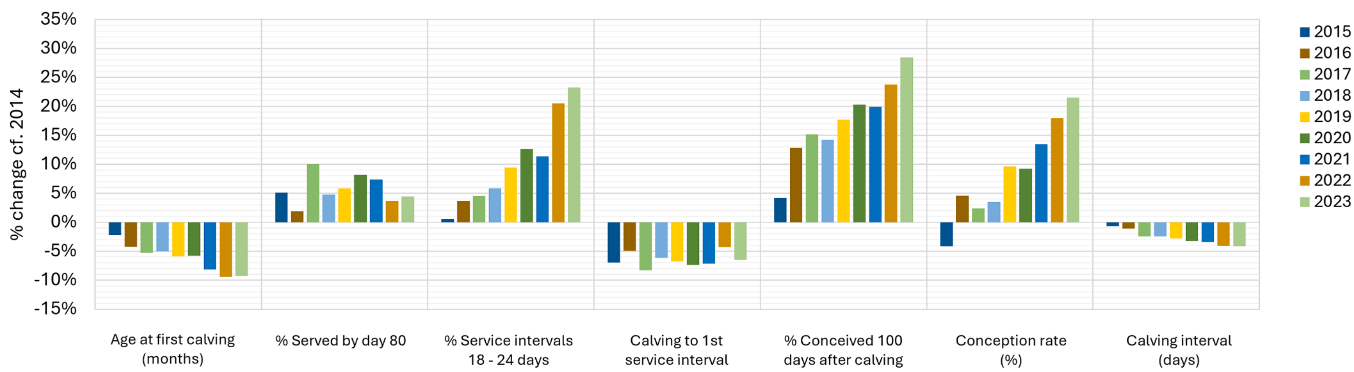

Fig. 3. Percentage change in median fertility parameters values compared to values in 2014.

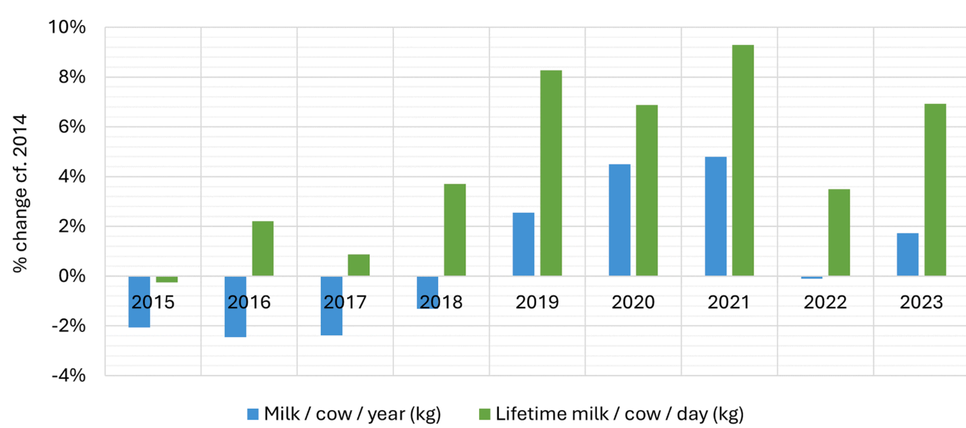

Fig. 4. Percentage change in median milk per cow per year (kg) and median milk per cow per day of life (kg) compared to herd values in 2014.

with a chronic (two or more consecutive) SCC $\geq$ 200,000 decreased from 10.3 % in 2014 to 7.9 % in 2022 and 8.1 % in 2023. The median herd's percent of cows dried-off with no SCC recordings $\geq$ 200,000 during a completed lactation increased from 39.7 % in 2014 to a peak of 51.0 % in 2023 (Fig. 7).

4. Discussion

While data for many dairy KPIs are widely available, longitudinal data for a mixture of consistently calculated KPIs in the same dataset is a rarity. Benchmarking of herd demographic, fertility, milk production and health-related KPIs for dairy herds has been conducted annually since 2010 using data from 500 randomly selected UK Holstein-Friesian herds (PAN Livestock Services, 2024). Herein, we used data from 195 of these herds to examine trends in KPIs from 2014 to 2023. Annual benchmarking provides farmers and technical advisers with accurate and up-to-date information on the variation in performance of commercial dairy herds. These findings highlight broader industry-level patterns which highlight potential areas for improvement and support policymakers in making more informed, strategic decisions. The results indicate that fertility, particularly conception and heat detection, and SCC related KPIs have all improved, milk production per cow has

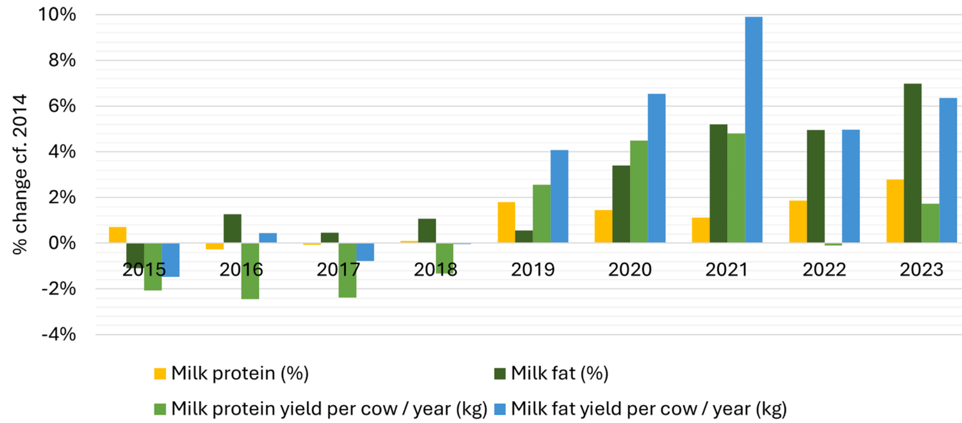

Fig. 5. Percentage change in median milk protein (%), milk fat (%), milk protein yield per cow / year (kg) and milk fat yield per cow / year (kg) compared to herd values in 2014.

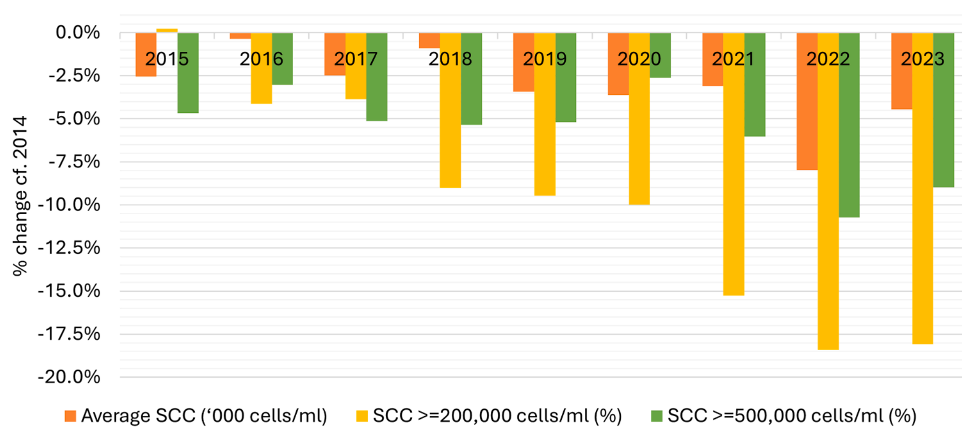

Fig. 6. Percentage change in median average somatic cell count (SCC) (cells/ml), and the median proportions of recorded cows with a SCC $\geq$ 200,000 or $\geq$ 500,000 compared to herd values in 2014.

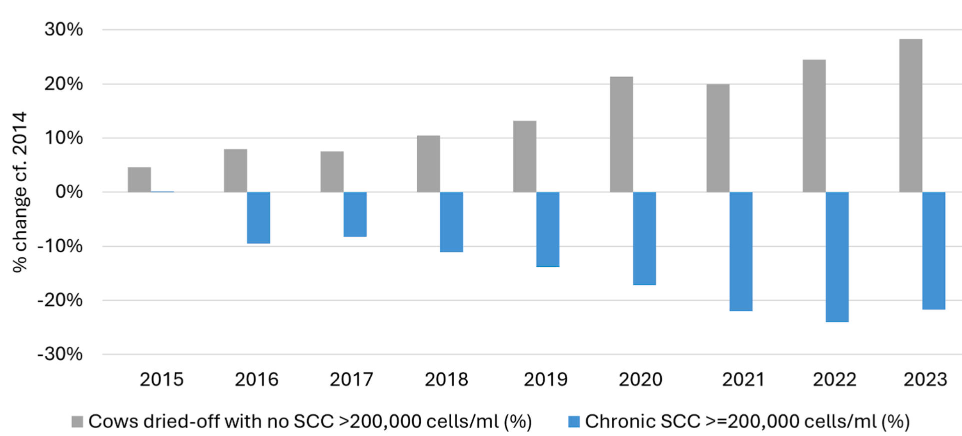

Fig. 7. Percentage change in median proportion of cows with chronic SCC $\geq$200,000 cells/ml and median proportion of cows dried-off with no SCC >200,000 cells/ml compared to herd values in 2014.

increased but appears to have peaked around 2021. However, the productive lifespan of dairy cows appears to be shortening. While herd sizes have increased, cows are exiting the herd at a younger average age, with higher exit rates which would require higher replacement rates to maintain the herds (Table 1).

The median herd size in this dataset increased by 15.8 % from 152 to 176 cows (Table 1). During the same period, AHDB estimated that the average UK dairy herd size had increased from 132 to 160 cows (AHDB, 2023a). This indicates that the 195 herds sample is drawn from slightly larger herds, suggesting that milk recording herds tend to be larger. The median herd exit rate (increased from 22.7 % to 27.6 %) is in line with data from other countries. Estonia, The Netherlands, and Canada report cull rates of 26 % (Rilanto et al., 2020), 28 % (Kulkarni et al., 2023) and 29 % (Canadian Dairy Information Centre, 2023), respectively. Due to the nature of milk recording data, our data recorded the exit rate, not cull rate, so some cows which exited the herds may have continued their productive lives in another herd.

A previous analysis using the same data source as used here provided evidence that surplus heifer replacements are being reared, as 6.6 % of first lactation cows were removed without any attempt to breed, mostly within 120 DPP (Taylor et al., 2024). Such exits very early in a cow's first lactation would contribute to the increase in exit rate while at the same time having little impact on the overall proportion of first lactation cows within the herd, which remained between 27.8 % and 29.2 % over the 10-year period. In line with these observations implying that herds raise surplus heifers, De Vries (2017) suggests that there is an economic trade-off of the improving genetic merit of replacement heifers against the financial and environmental benefits of longevity. Decreases in median productive life and median age at exit (Table 1, Fig. 2) suggest that UK farmers, are prioritising the improved genetic merit of replacement heifers at detriment to potential financial and environmental benefits of longevity. The average productive lifespan for high-producing dairy cows is well documented across a wide range of approximately 3.0 to 4.5 years (De Vries, 2020; Kerslake et al., 2018; Pinedo et al., 2014). In agreement, our data demonstrated that the median productive life decreased from 4 years 25 days to 3 years 9 months 12 days (Table 1). Therefore, dairy cows are exiting the herd before the optimal dairy cow productive lifespan of 5 lactations (De Vries, 2020). This study was based on herd-level data which does not provide a detailed picture of cow removals at each and every lactation. Future work could utilise cow-level data detailing the parity number and days post-partum of each cow at exit to determine how cow replacement and retention strategies may have changed over time.

Moreover, farmers are under increasing pressure to meet environmental targets, for example, the UK Dairy Roadmap challenges the industry to be net zero by 2050 (Dairy UK, 2021) and increasing the productive lifespan of dairy cows is a viable way to reduce the climate impact and to improve the profitability of dairy production (Grandl et al., 2019). Assessing the environmental impact of individual herds, through carbon footprint or greenhouse gas emissions calculators, has become integral to milk production contracts. However, there is currently a lack of standardisation across these calculators (Dairy UK, 2023). Until these environmental tools are standardised, the dairy industry could focus on productive life as a proxy for at least a component of environmental efficiency.

Some fertility data, mainly individual services, can only be recorded by the farmer and it is not feasible to check that all services are accurately recorded. This affects the accuracy of individual herd's KPIs for serves per conception and conception rates. The only data that can be fully relied on are calving dates, and by subtraction, conception dates. The calving dates of freshly calved cows are recorded by the milk recorder at each routine visit and must also be recorded when new calves are registered in the official identification and registration database. So, age at first calving, calving to conception and calving to calving intervals are reliable. Conception rate and serves per conception are KPIs of high interest to farmers so are included in annual KPI report (PAN Livestock Services Ltd., 2024) and this study. Moreover, the long-term trends in these KPIs are consistent with other fertility KPIs and considering the samples size ($n = 195$) any inaccuracies in service data in some of the herds should have a minor effect on the median values and are unlikely to systematically impact overall KPI trends.

Cows within the 195-herd cohort were younger at first calving, more likely to be served by 80 DPP and have conceived by 100 DPP with a shorter calving interval in 2023, compared to 2014 (Fig. 3, Table 1). Efficiency at each stage of the fertility timeline is crucial for the avoidance of involuntary culling and to support sustainability. For example, in a 200-cow herd producing an average of 8500 kg of milk per cow annually, and assuming a milk price of £0.38 per litre and feed costs of £340 per tonne, each cow that exceeds the average calving interval of 397 days incurs an additional cost of £4.88 per day (Kingshay, 2024). Improvements in fertility KPIs could be attributed to an increased use of KPI targets and genetic advancements. UK farmers have been encouraged to aim for a series of fertility KPI targets, such as; ≥70 % of cows should have been served within 75 to 80 DPP and ≥70 % of cows should have conceived within 100 to 120 DPP (Smith et al., 2014). Meanwhile, the introduction of holistic genetic indexes, such as the Profitable Lifetime Index (PLI) has allowed farmers to select sires based on a range of parameters including milk yield, fertility and longevity (AHDB, 2025), as opposed to focusing on milk yield alone (AHDB, 2024). Considering the plethora of factors known to influence dairy cattle fertility, including nutrition, genetic selection, reproductive management, heat detection and the interpretation of fertility data, attributing these improvements to one factor is not feasible (Crowe et al., 2018). Nevertheless, moving forwards, the development of fertility phenotypes and genomic markers combined with the increased use of activity monitors and improved breeding protocols is expected to support the observed improvements in dairy cattle fertility (Crowe et al., 2018).

The median herd's milk production parameters, including average milk yield per cow per year and milk yield per cow per day of life, peaked in 2021, at 8797 kg and 12.8 kg, respectively (Fig. 4). Up to 2021, the AHDB (2023d) reported a similar trend but with slightly lower annual milk yields, peaking at 8210 litres, compared to 8797 kg in our cohort of 195-herds (Table 1), reinforcing that cows in milk recording herds typically record higher milk yields (Balaine et al., 2020). Furthermore, in partial agreement with our data, the ADHB (2023d) reported a reduction in annual milk yields in 2022 (8173 kg) but production increased to above 2021 levels in 2023 (8219 kg). Differences in methods used to determine these values may limit comparability. The AHDB calculate milk yields based on processor data divided by the number of cows in the UK, whilst NMR data is based on recordings of milk output per cow. Outside of the UK, milk production per cow has also increased, the estimated median milk yield per cow increased from 7194 kg to 7813 kg, according to 13 EU countries which annually submitted data to the European Commission (Eurostat, 2024). Therefore, while our cohort of 195-herds showed slight reductions in milk yields in 2022 and 2023, and although differences in the selection of sampled herds make direct comparison difficult the data suggest that GB milk production levels still exceed milk production levels recorded in the EU. Meanwhile, the median milk protein increased by 2.8 % from 3.27 % to 3.36 % and median milk fat increased by 7.00 % from 4.00 % to 4.28 % (Fig. 5). Similar trends were observed in Irish pasture-fed dairy cows between 2012 and 2020 (Hayes et al., 2023). Milk composition is known to vary depending on the breed, genetics, stage of lactation, presence of mastitis and nutrition (Palmquist et al., 1993). Therefore, these observed changes in milk composition, were likely due to a combination of factors.

Many SCC related parameters improved between 2014 and 2023 (Table 1), including the proportion of milk samples ≥ 200,000 cells/ml and the percent of cows completing lactations with no high SCC recordings. Data from other UK sources; Quality Milk Management Services, TotalVet and Cattle Information Service, demonstrate similar reductions in the percent of milk samples with a SCC ≥200,000 cells/ml and percent of chronic (consecutive) high SCC samples (GB Cattle Health and Welfare Group, 2020). Countries outside of the UK have also observed improvements in SCC parameters, for example, the average SCC decreased in The Netherlands from 230,000 cells/ml to 174,000 between 2007 and 2019 (van den Borne et al., 2021), in the USA from 200,000 cells/ml to 179,000 cells/ml between 2012 and 2021 (CDCB, 2023) and in Ontario, Canada from 215,000 cells/ml to 167,000 cells/ml between 2013 and 2022 (AAFC, 2024). Thus, improvements in SCC control have been observed internationally. These improvements are likely due to a series of national control schemes, such as the UK 5-point mastitis control plan (More, 2009), accompanied by incentives or sanctions applied by milk buyers through milk contracts (Bradley et al., 2002).

5. Conclusions

Increased utilisation of industry adopted KPIs for benchmarking, setting targets and monitoring progress, alongside control plans have helped drive improvements in fertility and SCC. However, milk production appears to have peaked and the longevity of cows appears to be worsening. However, the percent of cows in lactation 1 has remained stable despite the average number of lactations completed for cows exiting the herd being fewer. Considering the increasing pressure on the dairy industry from consumers to become more sustainable, perhaps the industry should focus on productive life as a proxy for environmental efficiency, with the aim of increasing the average productive life of cows rather than focussing exclusively on lactation yields.

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CRediT authorship contribution statement

Emma N. Taylor-Holt: Writing – review & editing, Writing – original draft, Visualization, Project administration, Methodology, Investigation, Formal analysis. **Mohamad A. Kossaibati:** Writing – review & editing, Methodology, Formal analysis, Data curation, Conceptualization. **Kulwant Channa:** Writing – review & editing, Software, Resources, Methodology, Data curation. **James Hanks:** Writing – review & editing, Supervision, Project administration, Methodology, Investigation, Data curation, Conceptualization. **Nicholas M. Taylor:** Writing – review & editing, Validation, Supervision, Methodology, Investigation, Formal analysis, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Supplementary materials

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